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MITHRAS STUDIES OF THE BOUNDARY BETWEEN OPEN AND CLOSED FIELD LINES

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The coupling between the solar wind, the magnetosphere, and the ionosphere was studied using data from multi-instrument campaigns. One study showed that, even under quiescent conditions, the polar cap boundary was quite active. Repeated disturbances in particle precipitation and electric field were observed at intervals of 10 to 20 minutes. Some of these perturbations propagated westward at a velocity of around 1000 m/s. It was argued that these perturbations are the ionospheric signature of rapid increases in the midnight-sector magnetic reconnection.

In a separate study, the transition from active to quiet conditions was examined. The interplanetary magnetic field northward component switched suddenly from a northward to a southward orientation. The ionosphere responded within about two minutes: the electric field intensity diminished, and the F-region large and small scale irregularities changed dramatically. This response time is much shorter than had previously been assumed.

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I INTRODUCTION

This is the Year 1 Annual Report on AFOSR Contract F49620-92-C-0011 (SRI project 3245). The goals of the project are to study the underlying mechanisms that control the coupling between the solar wind, magnetosphere, and ionosphere. In particular, the investigations focus around the following four questions:

(1) What is the relative importance of the various factors that control the overall convection in the ionosphere magnetosphere system? Such factors include the parameters of the interplanetary medium, substorm activity, and season.

(2) When solar wind conditions are relatively stable for prolonged periods, what is the configuration of the ionospheric density, and electrodynamic parameters? In particular, what is the configuration when the energy input from the solar wind is minimum?

(3) When solar wind conditions change, or when a sudden release of energy occurs within the magnetosphere, how does the pattern of ionospheric electrodynamic parameters evolve with time?

(4) How does the reconnection rate change with solar wind conditions? What is the local time distribution of the reconnection electric field? What is the role of dayside and nightside reconnection in driving the whole convection pattern?

II RESEARCH ACCOMPLISHMENTS

A. IONOSPHERE-MAGNETOSPHERE COUPLING DURING QUIET CONDITIONS

We have focused our effort on studying the nightside ionospheric configuration during a prolonged quiet period. We analyzed data obtained during one of the MITHRAS campaigns on 12 and 13 January 1989. Observations from the Sondrestrom incoherent scatter radar were combined with those from the DMSP satellite, optical instruments, and the Goose Bay HF radar. This work was described in the paper "Quiet-Time Intensifications Along the Poleward Auroral Boundary near Midnight," submitted to the *Journal of Geophysical Research.* (A copy of the paper accompanies this report.)

The observations took place when the Interplanetary Magnetic Field (IMF) was unusually constant and directed approximately along the Earth-Sun line. This field configuration led to stable geomagnetic conditions. DMSP data revealed that the overall ion and electron precipitation boundaries and energy flux did not change appreciably during this period, and the electrostatic potential drop across the polar cap remained very small. The small ionospheric electric fields are consistent with the fact that the interplanetary electric field was almost zero, which corresponds to a minimum in the energy transfer from the solar wind to the ionosphere.

Despite the overall conditions of low precipitation levels and small electric fields, midnight-sector observations revealed that, on a small scale, the electric field and auroral precipitation were extremely dynamic. Intensifications of the poleward-most auroral arc were observed every 10 to 20 minutes. These intensifications were associated with the appearance of a new arc poleward of the previous most-poleward arc. Individual arcs then drifted equatorward at a typical velocity of 270 m/s.

About once per hour, stronger intensification events took place which have some resemblance to small substorms. One such event was studied in detail, and had the following characteristics:

(1) Fading of the poleward-most arc was followed by a rapid increase in precipitation (E-region electron density increased by about an order of magnitude).

(2) A new arc formed poleward of the existing arcs.

(3) A southward plasma-drift disturbance propagated through the Sondrestrom and Goose Bay fields of view. (This disturbance corresponded to an 100% increase of the southward drift velocity that propagated westward at speeds of about 1000 m/s.)

(4) The electric field disturbance was associated with an increase in the plasma flow across the poleward boundary of the auroral oval and with a local increase in the reconnection rate.

(5) A simultaneous DMSP pass revealed the presence, poleward of the auroral electron boundary, of ion precipitation similar to "velocity-dispersed ion structure events" that have been associated with rapid flow bursts in the plasma-sheet boundary layer.

This work represents the first detailed analysis of the rapid changes in the precipitation and plasma convection that occur at the polar cap boundary during periods of quiescence. The velocity disturbances that were seen to travel through the field of view of both the Sondrestrom and Goose Bay radars are interpreted as the ionospheric signatures of transient reconnection in the midnight sector.

B. MAGNETOSPHERE-IONOSPHERE COUPLING DURING RAPIDLY CHANGING IMF CONDITIONS

In collaboration with Dr. Michael Ruohoniemi, we also studied the response of the auroral ionosphere when the IMF abruptly changed from southward to northward. These

data corresponded to a multiday period of worldwide observations. The period was part of a combined Sundial, GISMOS, and MITHRAS campaign on 1 through 6 June 1987. (A copy of the paper, now accepted by *Annales Geophysicae*, France, also accompanies this report.)

The transition in the IMF was observed in the 11-13 UT interval (~ 8-10 MLT) on 1 June 1987 by the IMP-8 satellite which was located upstream of earth at a distance of 36 R_E. The ionospheric response in the 70° to 80° invariant latitude interval was monitored by the Goose Bay HF coherent-scatter radar, and by the Sondrestrom incoherent-scatter radar. The existing plasma convection observed by the two radars beforehand exhibited large velocities (500-1000 m/s) and stable long-term trends, consistent with the pattern expected of the then-prevailing $B_z < 0$, $B_y > 0$ conditions. The plasma flow rapidly diminished in response to the IMF transition. The electron density measurements made by the Sondrestrom radar in the meridional plane showed that the ionosphere had been rich in structure with the active deposition of ionization by particle precipitation; subsequently, it resembled more an inactive, unstructured mid-latitude configuration. There was a corresponding dramatic decrease in the amount of backscattering observed by the HF radar. The ionosphere began to show the effects of the IMF transition about 2 min after its probable arrival at the magnetopause boundary.

The interesting aspect of these observations is that the response time of the ionosphere is much shorter than expected. This response time had been estimated from Eiscat data to be around 10 minutes. Here, the time is barely larger than the Alfven propagation time from the magnetopause (1 to 2 min), which implies that the ionospheric reconfiguration takes place within seconds.

III FUTURE PLANS

We plan to further pursue our efforts by examining other coordinated data sets. We have started to examine Sondrestrom and Goose Bay data from the January 1992 campaign. These observations also corresponded to IMF B_z north conditions (B_z = + 5 nT). The radar was in the post-noon local time sector. These data have been selected because the

IMF B_y component was very large ($B_y \sim -20$ nT). The Sondrestrom radar data showed successive F-region maxima and minima moving equatorward, even though the E $\times$ B drift was poleward. The maxima were correlated with rapid rotations in the plasma drift and intensifications of its northward component. These events were also correlated with changes in the electron temperature which suggest that they were caused by soft-particle precipitation. Possible interpretations are now being evaluated, including an enhanced reconnection electric field propagating into the region of closed magnetic field lines, and plasma injection in the low-latitude boundary layer of the magnetosphere, as has been observed from the VIKING satellite.

In addition, we are planning other campaigns of observations. One such campaign will take place from 15 to 30 March 1993. It is a collaborative effort with Prof. Michael Mendillo, Rick Doe and Daniel Nottingham from Boston University, Dr. Larry Lyons and Gerard Blanchard from Aerospace Corporation, Dr. Hans Stenbaek-Nielsen from the University of Alaska, and Prof. Robert Lysak from the University of Minnesota. We will operate the Sondrestrom incoherent scatter radar simultaneously with optical and other instrumentation. We plan to observe auroral emissions from electron precipitation (the 6300 and 4278 angstrom emissions) as well as from ion precipitation (the H_β emission at 4861 angstrom). Extremely high time-resolution data are also planned for a study, on the dayside, of the coupling between the ionosphere and magnetosphere by Alfven waves.

IV PAPERS AND ORAL PRESENTATIONS AT MEETINGS

A. PAPERS

de la Beaujardière, O., L.R. Lyons, J.M. Ruohoniemi, E. Friis-Christensen, C. Danielsen, F. J. Rich, P. T. Newell, "Quiet-Time Intensifications Along the Poleward Auroral Boundary Near Midnight," submitted to *Journal of Geophysical Research.*

Ruohoniemi, J.M., R.A. Greenwald, O. de la Beaujardière, and M. Lester, "The Response of the High-Latitude Dayside Ionosphere to an Abrupt Northward Transition in the IMF," accepted by *Annales Geophysicae*, France.

B. ORAL PRESENTATIONS

1991

- December AGU (San Francisco, California)

  O. de la Beaujardière, L. Lyons, H. Spence, E. Friis-Christensen, and C. Danielsen, "Ionospheric Electrodynamics and Estimates of the Reconnection Electric Field During Quiet and Stable Conditions."

1992

- January Royal Astronomical Society (London, England)

  O. de la Beaujardière, "Radar Studies of the Aurora."

- January G/MIST RAS Discussion Meeting, Society of Antiquaries (London, England)

  O. de la Beaujardière, "Satellite-Ground Comparisons of Space Plasma Phenomena."

- March International Conference on Substorms (Kiruna, Sweden)

  O. de la Beaujardière, "Substorms During Very Quiet Periods."

- May AGU (Montreal, Canada)

  O. de la Beaujardière, L. Lyons, E. Friis-Christensen, M. Ruohoniemi, and P. Newell, "Characteristics of Small Substorms Occurring During Quiet Periods."

- August URSI Commission G International Symposium (Fairbanks, Alaska)

  J. Watermann and O. de la Beaujardière, "Ionospheric F-Region Plasma Characteristics Associated with Magnetosheath-like Electron Precipitation."

- August — STEP Symposium - Johns Hopkins University (Maryland)

  O. de la Beaujardière, "Results from the GEM and CEDAR GISMOS Campaigns."

- December — AGU (San Francisco, California)

  O. de la Beaujardière, J. Watermann, and G. Lu, "Sondrestrom Measurements During the GEM Campaigns."

  J. Watermann, and O. de la Beaujardière, "Sondrestrom Incoherent Scatter Radar Observations of Ionospheric Plasma Parameters Near the LLBL Footprint."

  G. Lu, A.D. Richmond, B.A. Emery, O. de la Beaujardière, and F.J. Rich, "Ionospheric Convection Patterns Deduced for January 27-29."

  K.B. Baker, O. de la Beaujardière, L.R. Lyons, F.J. Rich, and C. Hanuise, "High Temporal Resolution 2-D Maps of Convection in the Cusp/Cleft: A Direct Measurement of the Merging Rate."